REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

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1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED *(From - To)*
04-05-2005	POSTPRINT Presentation	01-10-2003 -- 01-05-2005

4. TITLE AND SUBTITLE
BEAR Base Solar Power System

5a. CONTRACT NUMBER
F08637-03-C-6006

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER
62102F

6. AUTHOR(S)
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5d. PROJECT NUMBER
4915

5e. TASK NUMBER
C1

5f. WORK UNIT NUMBER
4915C19C

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
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8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
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Materials and Manufacturing Directorate
139 Barnes Drive, Suite 2
Tyndall AFB, FL 32403-5323

10. SPONSOR/MONITOR'S ACRONYM(S)
AFRL/MLQD

11. SPONSOR/MONITOR'S REPORT NUMBER(S)
AFRL-ML-TY-TP-2005-4613

12. DISTRIBUTION/AVAILABILITY STATEMENT
Distribution Statement A: Approved for public release; distribution unlimited.
AFRL/MLQ Public Affairs Case #05-032.

13. SUPPLEMENTARY NOTES
Document contains color images. Presented at the 2005 Joint Service Power Expo, Tampa FL, 4 May 2005.

14. ABSTRACT

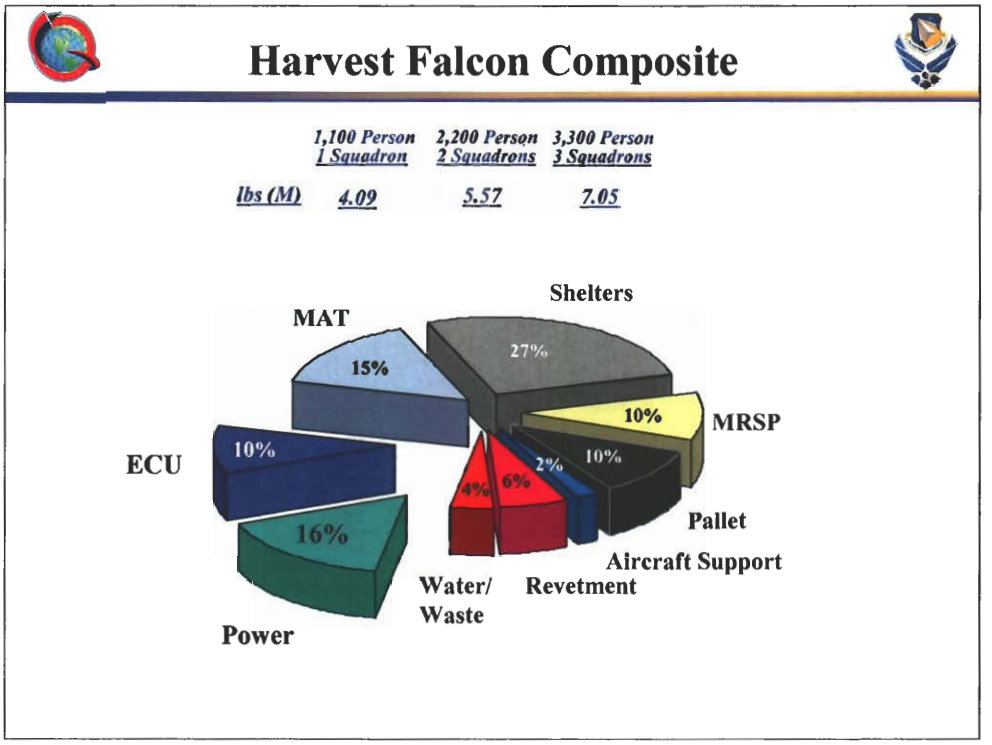
The Basic Expeditionary Airfield Resources (BEAR) base power system is a vital part of deployed Air Force operations. The Power system alone requires numerous aircraft sorties to deploy the generators, power panels, wiring, and fuel bladders. In order to keep the power on-line and functioning, additional aircraft sorties are needed to maintain the flow of fuel. Generating power by utilizing solar energy technology would greatly reduce logistics support requirements for BEAR Base power systems. Solar energy can offer the potential for significant weight and volume reduction, increased energy efficiency, and quiet mobile electrical power. the Air Force Research Laboratory Deployed Base Systems Branch Energy Research Group (AFRL/MLQD) is working to develop a lightweight, flexible, and efficient photovoltaic cells to integrate into the skin of Bare Base shelters. The combination of solar generated power with shelters will offer a more reliable power source that is low in thermal and noise signatures and pollution. This paper describes AFRL/MLQD's R&D effort to push forward the solar power as an alternative power source for deployed bases.

15. SUBJECT TERMS
Flexible Solar Cells, Photovoltaic, Alternative Power, Deployed Base Operations

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Reza Salavani
U	U	U	UU	19	19b. TELEPHONE NUMBER *(Include area code)*

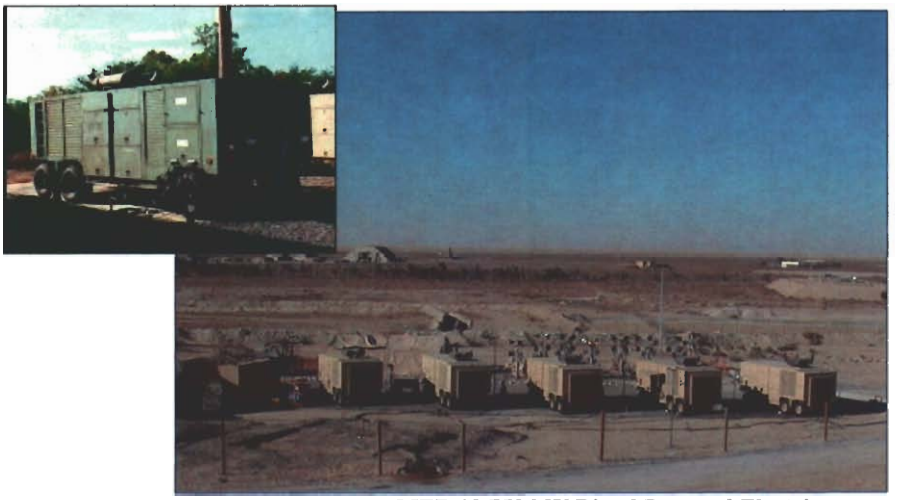
I will brief you on the Solar Power Research Activities within AFRL in support of deployed bases.

These are our research areas for the Deployed Base Systems Branch, MLQD. For today's meeting I'll be discussing our research efforts in Solar Power.



This pie chart shows a typical Harvest Falcon set. Take notice that Power generators are 16% of the weight and are the number one airlift requirement.

BEAR Base Electric Power
The Number-One Airlift-Intensive Requirement



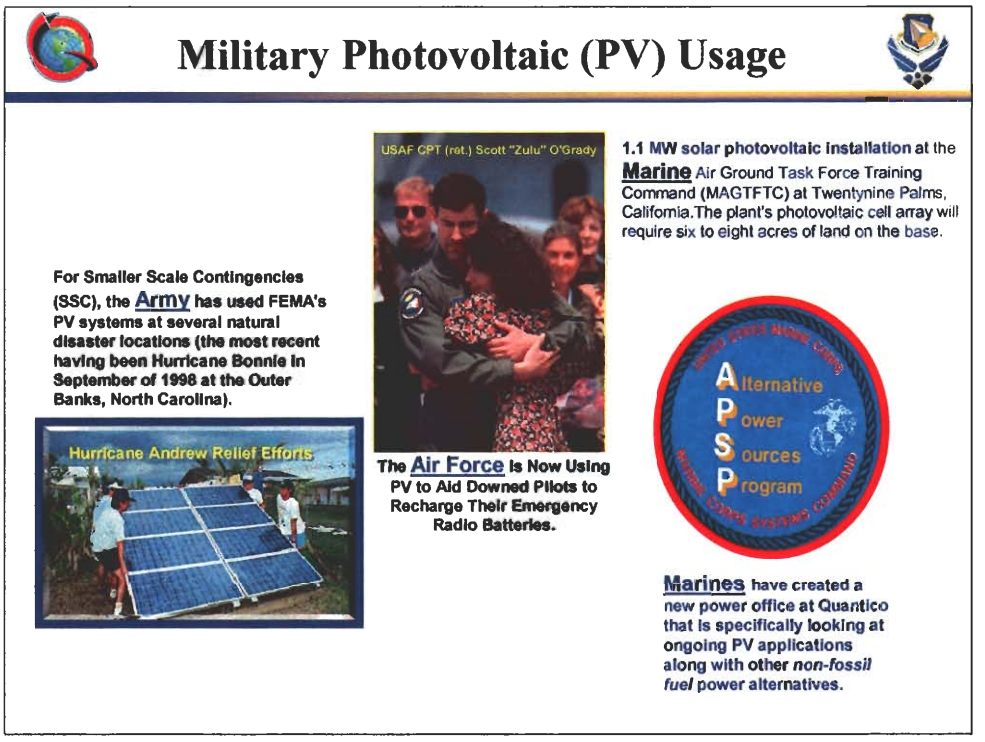
MEP-12 750 kW Diesel Powered Electric
Volume : (241" L x 96" W x 101" H) 1353 ft³ each
Weight: 25,374 lb each Cost: $165,033 Each

Here is a typical power plant in a deployed base. It consists of MEP-12 generators a heavy, noisy, high maintenance, and low efficiency diesel generator.

BEAR Base

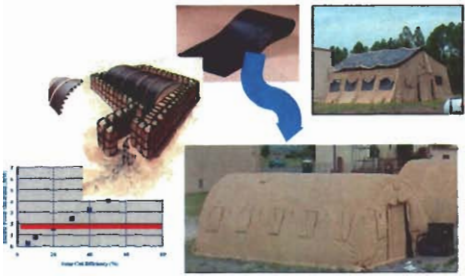
1100-man BEAR Base ~6 acres

Here is an typical deployed, 1100 man, BEAR Base in Bahrain covering almost 6 acres. Shown is a tent city with all infrastructure elements deployed. Power generators are deployed to provide electrical power to the base. Looking at this area it was obvious to us that solar would be a great addition to generate power.



So of course we looked to see if there had been military uses of photovoltaic technology. And there has been, the Army has employed various PV systems in smaller scale contingencies (SSC) over the past decade. Other services have used various PV powered modules for similar missions. The US Army uses diesel and gasoline powered generators for its off-the-grid power requirements. Using PV power as an alternative for off-the-grid power generation would benefit all services greatly. Historically, PV has not been able to compete with local electric power (i.e. "on-the-grid") utilities because of cheap electric power. However, off-the-grid, away from inexpensive power, PV is more attractive. That is why PV can often be found in less developed countries with limited natural hydroelectric potential or inadequate power grids. Today's major PV applications can be found in the middle of deserts and mountainous regions where it would be too costly for power companies to run power lines so why not the application of providing power to our deployed bases which can be found any various regions.

Solar Power Generation Shelters



Advantages

- ❑ Reduce the Logistics Tail
- ❑ Reducing the weight of military operations
- ❑ Lower the cost of operations
- ❑ Reduce the size and weight of diesel generators
- ❑ Reduce systems vulnerability to direct attack

To benefit greatly from solar energy you should have your site unobstructed and lots of sun. As you see from this deployed base there is definitely lots of unobstructed area where the tents are placed ~6 acres and our deployments have been in areas with high solar irradiance.
Bare base covers approx. shelter footprint ~6 acres of land. 1 acre ~ 4047 m2 => 24282 m2
1000W/m2 24.282 MW of power available a 15% efficient PV will produce 150W/m2

PV Technologies

Monocrystalline

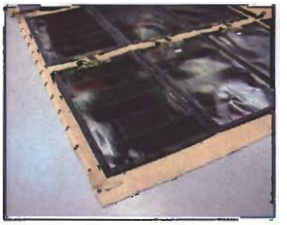
- $5 –8 /Watt
- 12-18% efficiency

***Polycrystalline**

- 5-12% efficiency
- $5-7/Watt

Amorphous Silicon (thin film)

- 4-6% efficiency
- $3-6/Watt



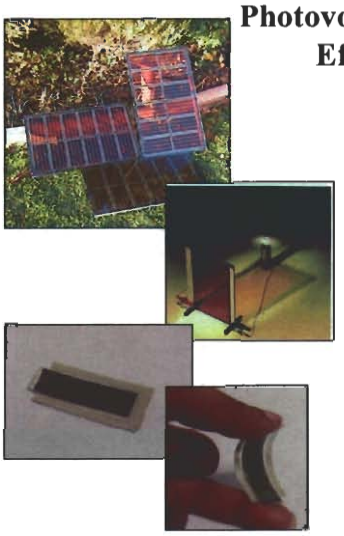
CIGS (CuInGaSe)

- 5-8% efficiency
- $8-10/Watt

Though it seems as a simple answer the questions we answer are what technology, does it exist, how much, how heavy. Shown here are current commercially available PV's and their general costs/watt and efficiency.

Dye Sensitized Solar Cell

Develop all-Solid-State Flexible Molecular Photovoltaic (Graetzel Cell) With Efficiencies of 15-20%

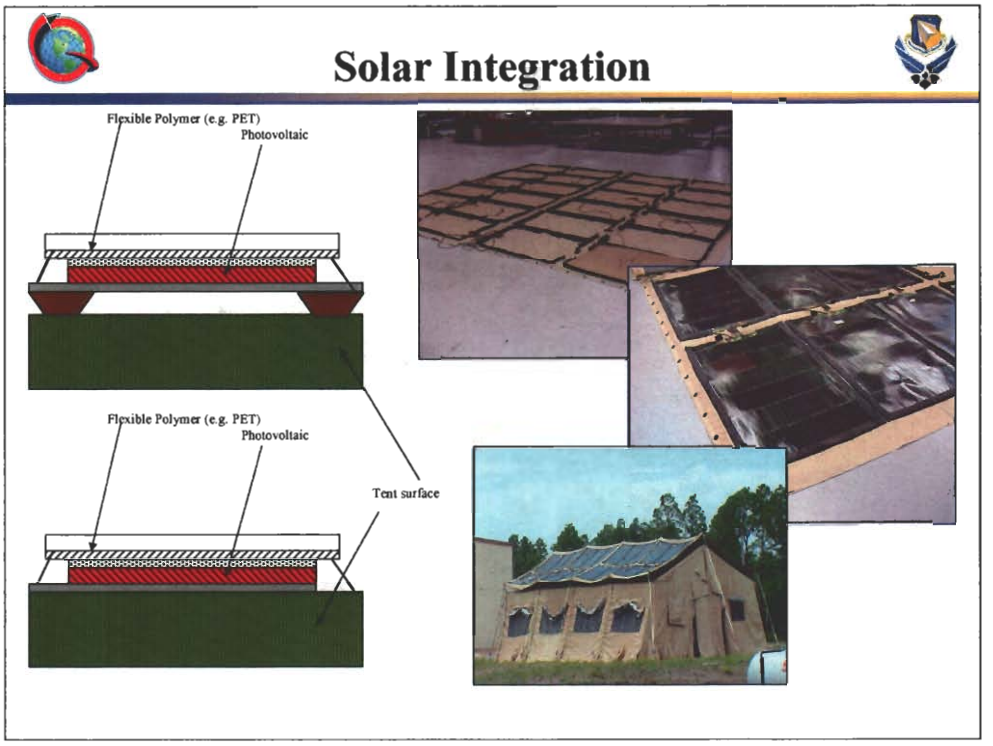


Advantages

- ❑Bifacial Configuration
- ❑Transparency for Power Windows
- ❑Spectral Absorption (Color) Can Be Varied
- ❑Outperforms a-Si
- ❑Compatible with roll-to-roll processing
- ❑Inexpensive

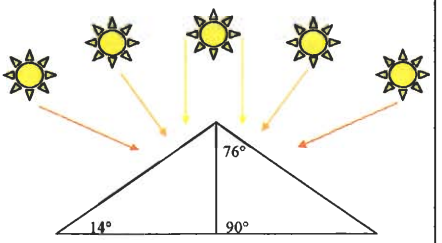
To achieve a low cost flexible solar power, we are working on the development of photovoltaic technology based on organic materials. These cells will be flexible, efficient, and cost effective suffering less from shading and heat as conventional PV devices.

Development of the cell has great potential to offer low weight, low cost renewable sustainable power that can be integrated into shelter systems.(cost) These cells can be printed using a roll to roll process significantly reducing the manufacturing costs and the materials are common which makes this really attractive.(fabrication)



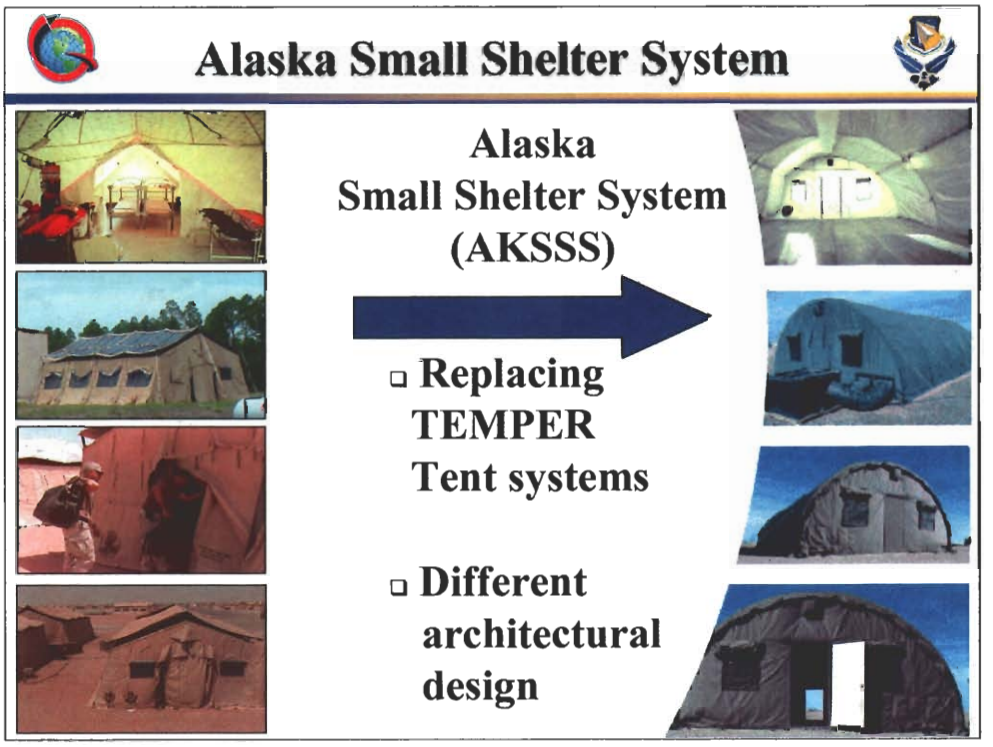
Overall we would take this technology and incorporate/integrate the shelter skin so that it is one piece as opposed to a separate component to attach as we have intially done with our Temper Tent. Overall we would like to take this technology and incorporate/integrate the shelter skin so that it is one piece as opposed to a separate component to attach.

Orientation & Prediction Model



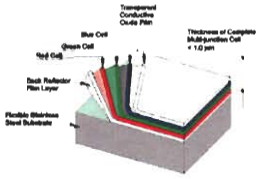
- ❑Copies 3/12 pitch of TEMPER Tent (14°).
- ❑Change orientation of model 360 degrees
- ❑Data recorded in lab
- ❑Eppley Pyranometer
- ❑Digital compass Module

The power available depends upon the position of the sun in relation to the architectectural structure supporting the array. Therefore we created orientation and prediction model to rotate 360 degrees at a fixed angle mimicking an A frame (Temper Tent Shelter)

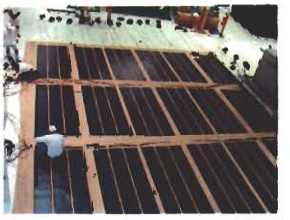


The AKSSS shelters are currently replacing the outdated 20-year old TEMPER systems, which are presently used throughout the military services.

Development of Solar Integrated AKSSS



- **AFRL/MLQD designed a Photovoltaic Integrated Small Shelter System**
- **Solar Integrated Technologies fabricated the cover**
- ***UNI-SOLAR* Triple Junction a-Si**



With the Air Force moving from the TEMPER shelter so must our research with respect to the Small Shelter System having a different architectural structure. The CIGS PV developed for the TEMPER would not do for the SSS, being research panels, we needed to take a proven technology to get more accurate data for a fielded situation.

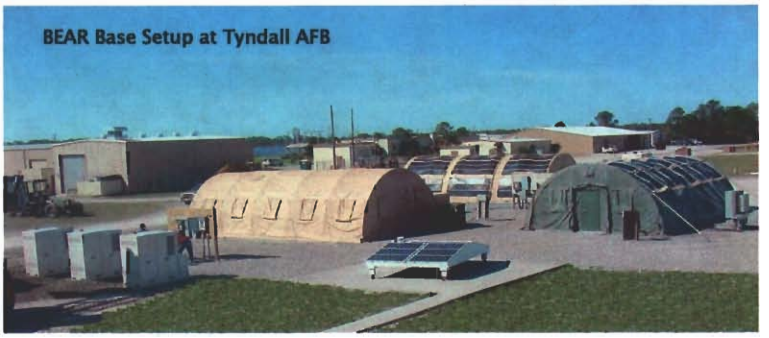
Solar Energy Dynamics Study

- Reliability &Durability
  - Visual Inspections
  - I-V Characteristics
  - Performance Degradation

- Energy Availability
  - Actual Power Generated
  - Temperature Vs. Performance
- Facility And Utility Demand Reduction
  - Reduction/Increase In Thermal Load
  - Power Demand

By integrating a technology, though at a lower efficiency than what we expect to achieve, that exists, is proven, and is available today we are able to examine and address issues of reliability and durability, energy availibility, and facility and utility demand reduction and assist us in our research for photovoltaic development for PV power generation shelters for the future.

Renewable Energy Tent City



Investigate A BEAR Power System That Includes Solar And Fuel Cell Power Generation In Support Of The Evaluation Of Current Requirements And To Form Advanced Power Transition Strategies.

The BEAR Base operations require electric power to run air conditioning, lights, kitchen, hospital, ect and keep critical mission functions operational. Fuel Cells and solar photovoltaic can provide uninterrupted electric power to these functions in three scenarios. Central power generation, distributed power generation, and back up power.

The picture shown is our Renewable Energy Tent City setup at AFRL/MLQ Tyndall AFB that emulates a BEAR base. It is equipped with air conditioning units, solar covers, and all lighting required. Generating solar power would greatly reduce airlift requirements. The advancement of solar cell technology as a supplement and in some cases a replacement for conventional electric power has provided a gateway for Bare Base Power systems using the sun as secondary fuel and maybe even one day as a primary fuel.

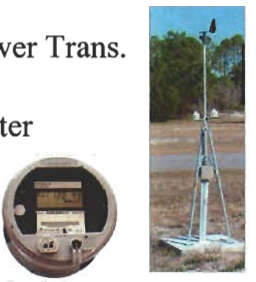
Our Tent City is continuing to grow. Here you see 3 shelters but there will be 4 and maybe 5 in the end. Of course we have the Alaska Cover which we had integrated with Uni-Solar Panels but we also have the CIGS integrated Temper Tent and We are working on the development of integrating organic solar cells in a shelter. In the end we will have 3 PV technologies two of which are existing technologies which are commercially available today and the other based the advanced photovoltaic technology that we are developing.

We also have our OPM which is acquired and recorded in the solar lab to aid in development of a computer model to simulate/predict power generated in a deployed setting given geographical information.

Instrumentation & Data Acquisitions

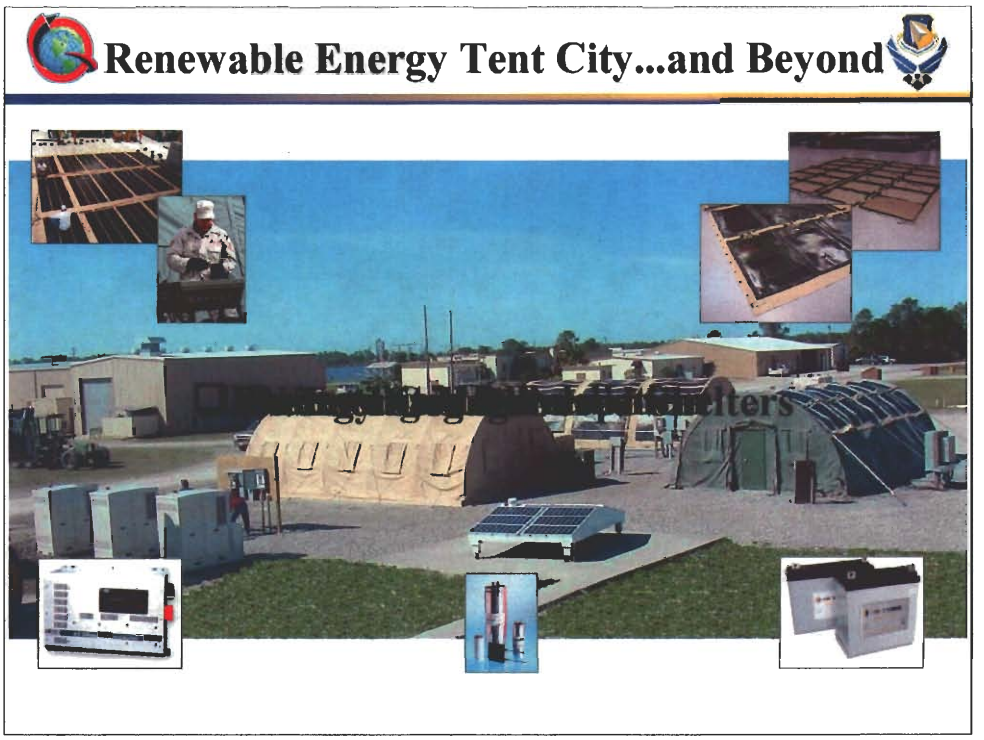
Data Acquisitions and Components:

- ❑ FieldPoint
- ❑ Current, Voltage, and Power Trans.
- ❑ POA Pyranometers
- ❑ Solar Tracking Pyranometer
- ❑ Weather Station
- ❑ kWh Meter



Parameters being monitored:

- ❑ Solar Module Temperatures
- ❑ Ambient Temperature
- ❑ Wind Speed
- ❑ Wind Direction
- ❑ Humidity
- ❑ Solar Irradiance
- ❑ Fuel Cell Generated Power
- ❑ PV Amperage & Voltage
- ❑ Shelter Loads
- ❑ Battery System



Our Efforts range from power production to distribution to energy storage. In addition to our Tent City we have a Solar Tracker with panels generating 1 kW of power which is fed into an inverter in the solar lab and used to power the data acquisitions in the Solar Control Laboratory in a Grid-Tied. It's great that it powers our solar lab, but we are also able to study its interaction with the grid as a viable option for a BEAR Base system with no formal energy storage device such as weighty batteries. Batteries are not required because the grid (fuel cell) supplies any extra demand.

Electrical Power Generation Without The Need For Heavy, Noisy, Generators Is Key To A Lighter, Leaner, Lethal Military Fighting Force.

Lightweight, Flexible Solar Cell Technology Allows The Power System To Be An Integral Part Of The Shelters, And Is Quiet Generation.

Fuel Cells Feeds The Demands When The Sun Is Not In Demand Or When Demands Exceed Solar Power Available, And Is Also "Quiet Generation" Allowing For Stealth Operation.

Combined, These Power Generation Systems Permit:

Distributed Generation

Power Available Any Time Of Day

Greater Reliability

Benefits And Uses Are Mission Specific And Must Be Identified. Solar & Fuel Cell R&D And Working With Industry Will Help To Develop The Technologies For Specific Military Needs

Questions